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Practical Studies on Soil Conservation in Reclaimed Sloping Land

—Establishment of Study Plots and Some Basic Soil Properties—

Kinzo NAGAHORI, Takao AMAYA, Manas LOSIRIKUL
Tadashi ADACHI, and Takeo AKAE[a)]
(*Laboratory of Land Consolidation*)

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Summary

In order to control soil erosion in reclaimed sloping lands among the mountains, first of all the important thing in case of the establishment of plot for repeating various experiments may be the interrelated uniformity of a study plot. The location of a study plot is inside of the development project area where there consists of most general and average slopes.

Due to the interior study plot was on the same slope and soil property, each of the divided A, B, C, and D sub-plots was thought of having the same conditions, and the aim of this experiment was to estimate whether the sub-plots could be regarded as an uniformity or not from their soil characteristics.

Soil samples were collected at the upper-, middle-, and lower points of four sub-plots and mixed together so as to evaluate their properties at large. The samples were analyzed to clarify such soil physical properties as specific gravity, porosity, soil structure, particle-size distribution, water retentivity (pF), erodibility, and so on. We then made clear of the general soil characteristics as well as investigated their uniformity among four sub-plots from these obtained results.

The results obtained can be summarized as follows:

1) The soil of study plot is an undeveloped structure, low in degree of aggregation which shows resistivity toward dispersion action, and low in porosity of supporting permeability and water retentivity. The pF values also substantiate these results.

2) Distribution of particle sizes indicates the property peculiar to Masa soil consisting of the uniform mixture of gravel to clay particles.

3) The study soil showed erodibility resulting from its high ratios of dispersion and erosion. Therefore, it was clarified that some proper erosion control practices have to be devised for the use of soil in the future and for agricultural activities.

4) According to the foregoing results, the differences in soil physical properties were not found among four sub-plots, thus they could be regarded as the same experimental plot and be used for carrying the further experiment.

Introduction

The study area, located on 400—500 m elevations at the Sera Plateau in the central part of Hiroshima, was blessed in natural conditions with little relief suitable for farmland reclamation. But, in addition to the low productivity because the cultivated fields were terrace paddy- and sloping fields, the average farm lot per household was few only 0.89 ha, so the government-operated farmland reclamation project (The plateau reclamation construction project of Hiroshima Chubu) has been started for extension of farm scale and stabilization of

a) Division of Agriculture, Shiga Prefectural Junior College

farmer economy[7].

However, owing to the reclamation of sloping plateau, the topography, vegetation, waterway, and so on will be changed from the former conditions and the runoff characteristic of basin be affected too. Consequently, in case of the occurrence of flood, sediment loss, etc. at the downstream basin which attributed to the amount of runoff water increases when it rains, the construction of such facilities as flood control and sand settling basin has also become necessary to this area. Moreover, the plateau which hold high permeability supported by natural vegetative covers will be changed in basin configuration and be reduced in water retention capacity after farmland reclamation which leads to the water shortage in cultivated fields of the downstream basin of reclaimed areas[8]. The problems can be resolved if the maintenance and management of reclaimed farmland are sufficiently carried out. Therefore for farmland reclamation, it is desirable to grasp the basin configuration correctly and to make a plan coping with it after reclamation. But the rather difficult problem is the clear and systematic clarification of runoff form because it is subject to area conditions.

As for the farmland reclamation of Masa soil zone in the study area, especially the sediment loss following surface soil erosion due to rainfall has become an important problem. Therefore, it is important from the viewpoint of conservation management to clarify how effectively control practices such as ridge direction method and mulching can conserve field soil[2,5,9].

To illuminate such above problems collectively, we considered the implementation of investigation that be mentioned in the next. First, we aimed at gaining information to conduct the design of a reasonable drainage and the estimation of water use in the downstream basin based on investigations related to the change in runoff discharge at normal time and rainfall time in the study plot as well as on the measurement and analyse of total runoff discharge and its peak from the reclaimed area. Moreover, we implemented the investigation regarding the effect of farm management method on soil erosion by setting up the erosion experimental plot for clarification of reasonable conservation measures of the reclaimed land. The study plot is on uniform slope in the Enogouchi region of the plateau reclamation construction project of Hiroshima Chubu.

This report describes the results of soil test that carried out at the beginning of experiment of the erosion study plot. For conducting and repeating the concrete experiments on farmland conservation methods positively, first the guarantee of uniformity in every sub-plot that divided from the study plot for conducting the comparative study becomes a prior condition. Therefore, we conducted these inspection through the clarification of some soil physical properties and made a judgment of a study plot selection's propriety.

Outline of Study Plot

The location of study plot is in the fields of Enogouchi region, Sera district, Hiroshima prefecture which be a part of the government-operated Hiroshima Chubu plateau farmland reclamation project and its outline is as shown by plain and longitudinal sections in Fig. 1. The study plot was an oblong one on 4.5° uniform slope with 30 m in length and 20 m in width along the slope direction. It was divided equally into 4 sub-plots which each of them had the smallest plot unit of 5 m×30 m dimensions and named plots A, B, C, and D, respectively (Fig. 1.).

Most important point for the establishment of these plots is the beforehand consideration for every plot to be possessed of the same experimental conditions. Accordingly, the boundary of every plot was separated by galvanized iron sheets to protect the entrance and exit of runoff, and their outside were surrounded with small ditches for drainage. The sedimentation tanks were constructed with reinforced concrete with dimensions of 5 m length, 1 m width and 0.65 m depth at the lower end of slope in each plot. Soil losses in every plot were obtained by measuring deposited soils from the tanks. In addition, rainfall data were obtained from the rain gauge set near the experimental plots. The details of the experimental plots and sedimentation tanks are shown in Figs. 1, 2 and 3.

Experimental Methods

In reclaiming farmland from sloping land between mountains, the ways how to conserve soil surface loss by rainfall at the time of reclamation and conserve soil loss following farm managements of sloping farmland after reclamation have become the important problems.

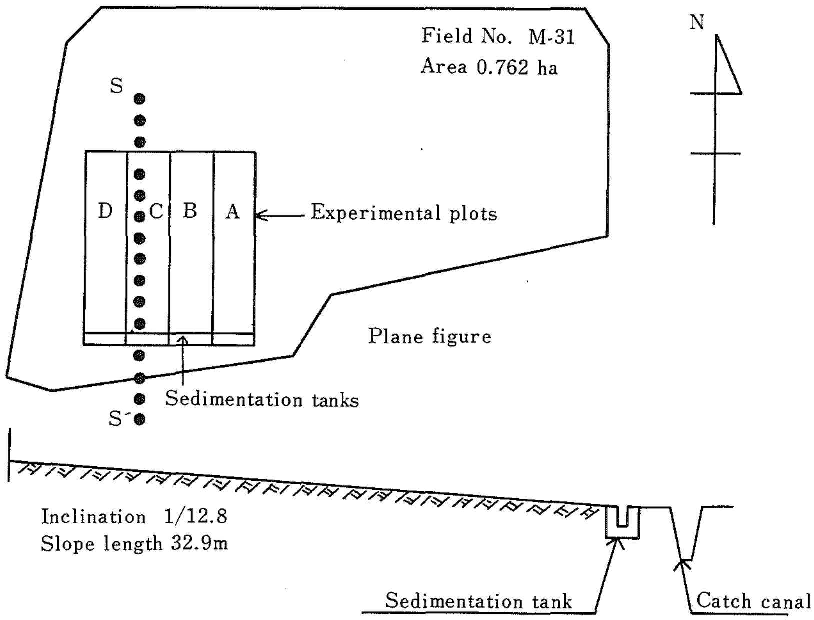

Fig. 1. Layout of the experimental plots and their sedimentation tank.

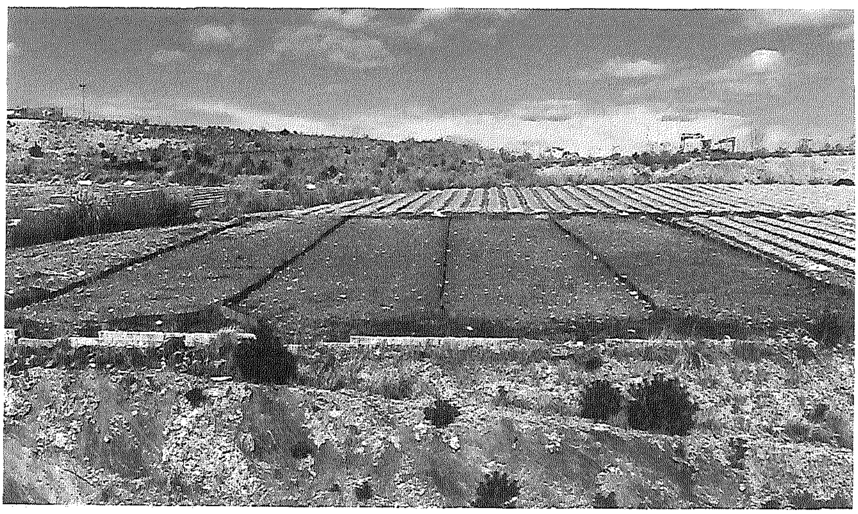

Fig. 2. Experimental plots.

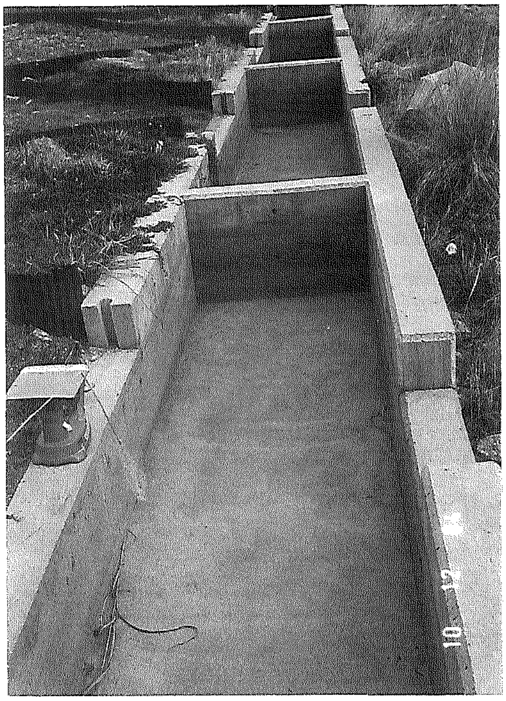

Fig. 3. Sedimentation tanks.

As previously stated, the soil erosion experimental plots were constructed at the field after reclamation and arranged to conduct a research study positively by repeating various conservation practices. For such purpose, it is important firstly to inspect every experimental plot whether they have the same conditions or not. Accordingly, the soil samples were taken from every plot for the analyses of specific gravity, soil dispersion, particle-size distribution, water-stable aggregates, percolation capacity, water retentivity, and so on[3]. And we used these results to inspect the composition, structure, water retention capacity, erodibility or water resistance of field soil, and then their results were compared and investigated minutely for deciding the uniformity of every experimental plot. Additionally, the soil samples were taken from the upper-, middle-, and lower points of each plot and mixed together taking a measure that can estimate soil property of the whole plot.

Results

1. Specific gravity and densities

The result of specific gravity (JIS 1202—1978) is as shown in Table 1, and in all plots amounts to nearly 2.65 which equal to that of the general soil.

Table 1. Specific gravity values meausred according to JIS A 1202-70

Plot	A	B	C	D
Specific gravity	2.65	2.64	2.64	2.64

Next, we sought for dry density, wet density and porosity to observe the development degree of soil structure and indicated them in Table 2. Generally, the most fine conditions for the cultivated soil's porosity are to the extent of 60%[4], whereas those of the all experimental plots have a little low values. Soil porosity is concerned in the change of permeability ; if the porosity is small as well as permeability is low, it has come about that those will bring about an increment of surface runoff and urge erosion. Therefore the experimental soil is presumed as erodibility, as observed by this porosity.

Table 2. Density and porosity

Plot	Dry density (g/cm³)	Wet density (g/cm³)	Porosity (%)
A	1.36	1.68	48.7
B	1.42	1.79	46.2
C	1.47	1.80	44.3
D	1.49	1.87	43.6

2. Particle-size distribution

Distribution of soil particle sizes in every plot was carried out according to JIS A 1204-1980. Furthermore, we analysed both the particle sizes of less than 0.002- and 0.05 mm by means of pipette method for calculating dispersion and erosion ratios.

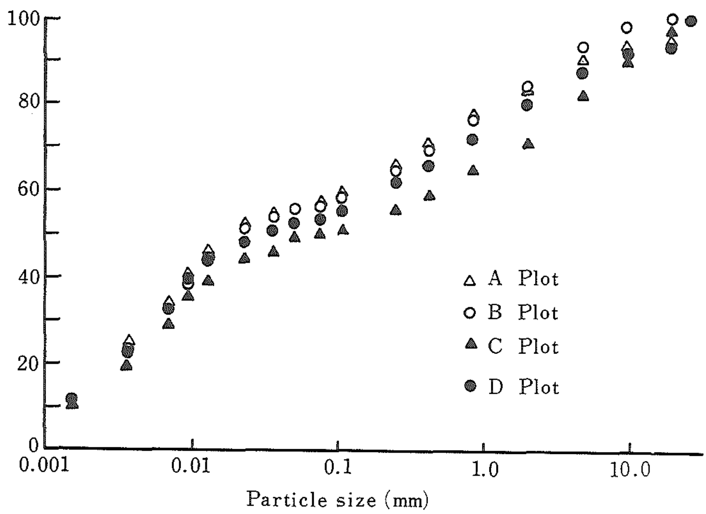

Fig. 4. Results of particle-size analysis of four plots.

The result of particle-size distribution is as Fig. 4. As the accumulated curve of all plots indicates in gentle inclinations and close vicinity, it may safely be said that their content state of sand, silt and clay parts have a resemblance. Moreover, there are indications of tendency peculiar to Masa soil which its distribution generally holds every particle sizes evenly.

3. Water-stable aggregates and water retentivity

We carried out the analyses of water-stable aggregates and water retentivity so as to evaluate the degree of soil sturcture development and the circumstances of water environment that regarded as main factors affecting soil erosion. In brief, the soil developed in aggregate structure has large porosity, good water retentivity and favorable permeability for not only plant growth but also its strong resistance against erosion by wind and water, and these are considered as important factors in estimating their countermeasures from the viewpoint of soil conservation.

Table 3. Degree of aggregation (Standard particle size 0.1 mm)

Plot	A	B	C	D
*Degree of aggregation	29.29	21.67	20.58	26.65

$$\text{*Degree of aggregation} = \frac{\text{A. W.} - \text{R. P. W.}}{\text{T. D. W.} - \text{R. P. W.}} \times 100$$

Where A.W. : Aggregate weight, R.P.W. : Remaining primary particle weight,
T.D.W. : Total dry weight.

1) Water-stable aggregates

First, we try to investigate the conditions of aggregation degree. The degree of aggregation expresses the percentages of particles of those less than the standard particle size that can form aggregates, and from Table 3 all plots show low values in aggregation of less than 30% at the 0.1 mm standard particle size which imply the underdevelopment of aggregate structure.

Next, the result of water-stable aggregates is given as Fig. 5. But the experimental method for water-stable aggregates has not been standardized yet, so the soil engineering academy method were applied here. First, we sieved the soil sample through a 9.52 mm screen, weighed 40 g. of soil that passed through the sieve and left the sample in water using a beaker method for 20 hours or more, and then sieved it in water by water-immersed sieving method using a nest of standard sieves (2, 1, 0.5, 0.25, and 0.1 mm). We used 6% of hydrogen peroxide solution for organic matter decomposition, and 0.4 N of sodium hexametaphosphate solution for soil dispersion.

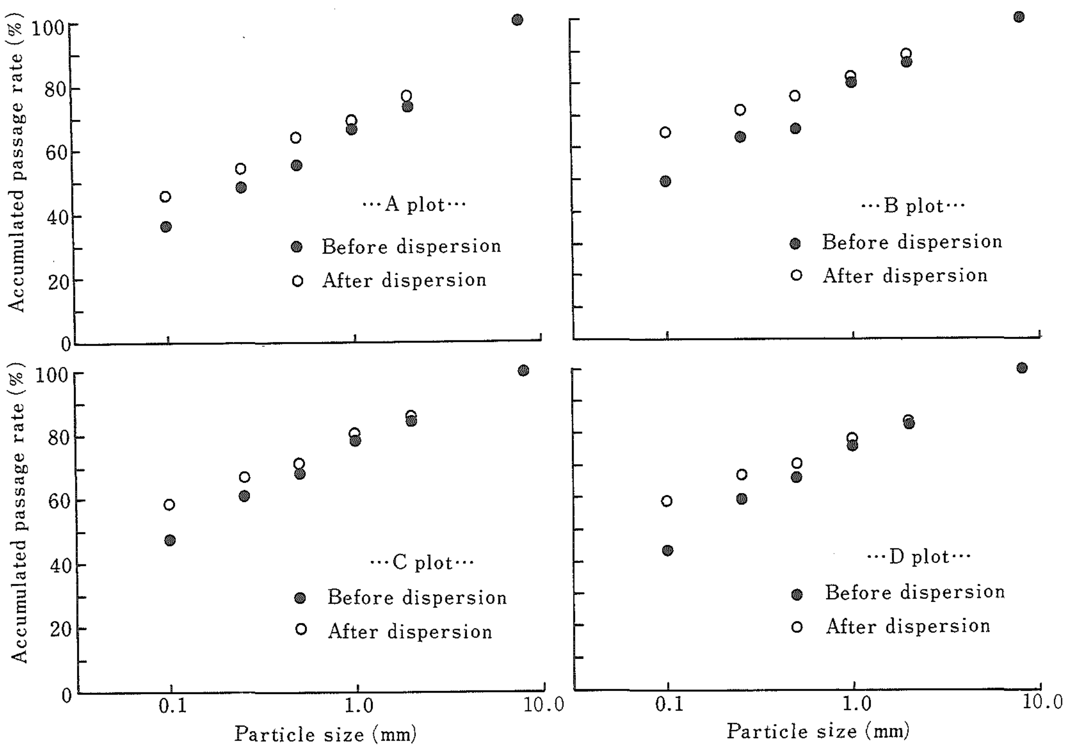

Fig. 5. Results of water-stable aggregate analysis of plots A, B, C, and D.

There were indications from these results that the aggregation of particles in the range of fine particle size has much progress as compared with particles in coarse particle range. But the aggregation has not developed by and large. For the purpose of reference, the experimental result of the neighboring aggregated surface soil (developed field) is presented in Fig. 6.

From Fig. 6, the differences between values of before- and after dispersion are obvious indicating the development of aggregation. When we inspect the above result, it became clear that the aggregation of plot soil is underdeveloped and has little differences among the plots.

2) Water retentivity (pF experiment)

We sought for the pF-moisture ratio curve to study water retentivity. We used suction method for measuring the ranges of pF 0−2.0 and centrifuging method for pF 2.0−4.2. Their results are given in Fig. 7.

When we appraise soil conditions from the result of pF-moisture ratio curve, the experimental soil remains unchanged from that of the beginning of development and has underdeveloped conditions. In other words, the slope of curve from the low pF to high pF is sharp that implies the very low holding capacity of available water for upland fields. For reference to these comparative study, the pF-soil moisture curve values of a second year cultivated field, and of a well-developed structure's surface soil and an undeveloped subsoil of neighboring, well-managed upland field are shown in Figs. 8 and 9. The pF values of every plot are equal to those of subsoil below the well-managed cultivated surface soil. Therefore, the desirable pF values for a future farmland or conservation viewpoint should consist of such a condition as shown in Fig. 9.

4. Erodibility

We measured the Middleton's dispersion and erosion ratios for clarifying the circumstances of a study soil's erodibility[1],

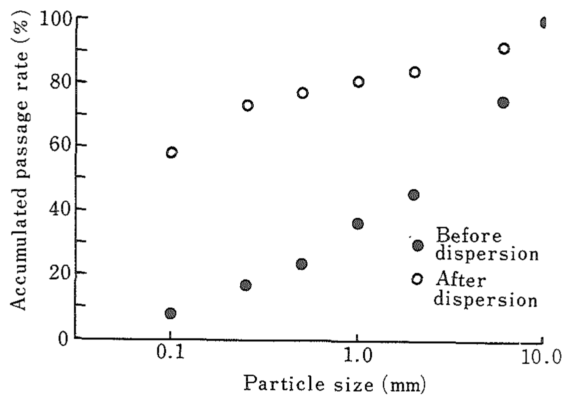

Fig. 6. Degree of aggregation of surface soil in developed field.

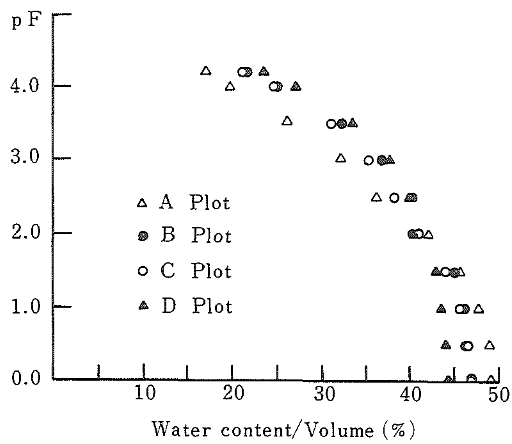

Fig. 7. pF-soil moisture curve in four plots.

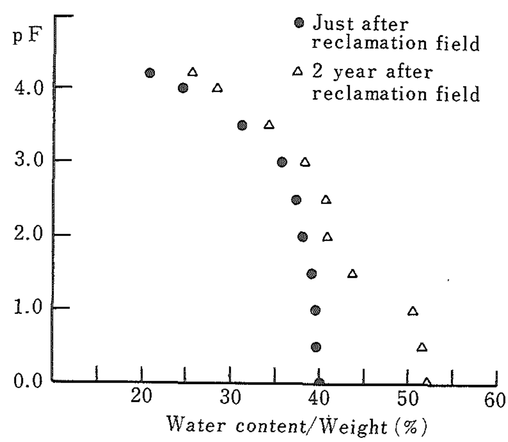

Fig. 8. pF-soil moisture curve of a 2 year after reclamation field.

and their results are presented in Table 4.
Here,

$$\text{Dispersion ratio (Dr)} = \frac{\text{Content of particles} < 0.05\,\text{mm by water dispersion}}{\text{Content of particles} < 0.05\,\text{mm by agent dispersion}} \times 100$$

$$\text{Erosion ratio (Er)} = \frac{\text{Dispersion ratio}}{\text{(Colloid content/Moisture equivalent)}}$$

Where, colloid content : the content of particles less than 0.002 mm and moisture equivalent: the moisture ratio at pF 2.7.

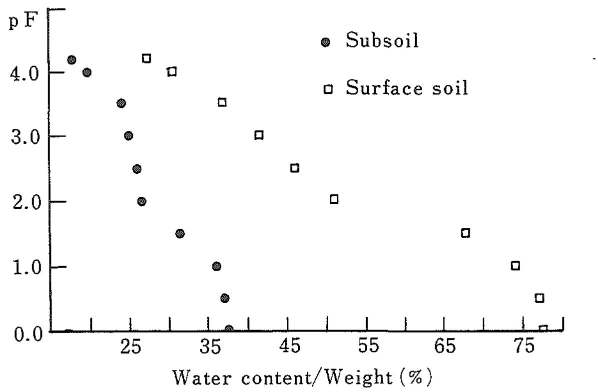

Fig. 9. pF-soil moisture curve of a developed field.

Table 4. Dispersion and erosion ratios

Plot	Division	Dispersion ratio	Colloid content	Moisture equivalent	Coll. cont. / mois. eqiv.	Erosion ratio
A	< 0.05 mm dispersion	44.6	14.0	25.2	0.56	79.1
	< 0.002 mm dispersion	40.7	14.0	25.2	0.56	72.7
B	< 0.05 mm dispersion	50.2	14.5	26.1	0.56	89.6
	< 0.002 mm dispersion	46.9	14.5	26.1	0.56	83.8
C	< 0.05 mm dispersion	13.0	13.0	26.0	0.50	103.4
	< 0.002 mm dispersion	13.0	13.0	26.0	0.50	101.6
D	< 0.05 mm dispersion	69.4	13.0	25.9	0.50	129.8
	< 0.002 mm dispersion	60.0	13.0	25.9	0.50	120.0

Table 5. Division of non-erosive and erosive soils (Middleton)

Division	Dispersion ratio	Erosion ratio
non-erosive	5.2−15.1	2.2−12.2
erosive	13.0−66.0	12.4−65.2

Table 6. Division of non-erosive and erosive soil (Japan)

Division	Dispersion ratio	Erosion ratio
non-erosive	> 20	> 30
erosive	> 40	> 80

Classification of the erosive and non-erosive soil by Middleton[6] is given in Table 5. But the judgment of non-erosive soil as erosive soil has been clarified by many Japanese researchers when these values applied to the Japanese soils, and the use of values as shown in Table 6 has proved to be appropriate for the Japanese soils. When we apply the results of Table 4 to Table 6, all will become erosive soils except erosion ratio of plot A, and if the erosion ratio of plot A approaches to about 80, it will result in erosive soils on the whole.

Discussion

To control soil erosion in the reclaimed farmland of sloping field among the mountains, first of all the guarantee of uniformity in the whole experimental plot in case of establishing it for repeating various experiments become important. There is no problem about the representativeness of located area of this experimental plot because this area has most general and average slope inside of the development project area. Moreover, due to the interior study plot was on the same slope and soil property, each of the divided sub-plots A, B, C, and D was thought of having the same conditions and the aim of this experiment was to estimate whether the sub-plots could be regarded as an uniformity or not from soil characteristics in every plot.

First, the average values of four plots amount to 2.64 for specific gravity, 1.73 g/cm^3 for dry density, 45.7% for porosity, and the particles of the particle-size analysis's result distribute uniformly from gravel to clay on the whole which be the indications of property peculiar to Masa soil. Next, when we study on soil structure from degree of aggregation, it may be said that the soil structure under 30% in all plots is an underdeveloped soil with common characteristics. Moreover there is no great change in pF which its values, expressed in term of moisture ratio, distribute in narrow ranges of 40 to over 20%. This signifies a phenomenon that commonly observed in case of the undeveloped structure of soil in reclaimed farmlands. It was also confirmed, from the experimental resuts of this study soil's erobibility, that the soil has a property susceptible to water erosion because its values exceed the criteria of dispersion ratio by more than 40 and of erosion ratio by more than 80.

From the said results, it is clear that we must pay attention to soil erosion control in case of conducting farm operation for the future upland crop because the soils of this reclaimed area are susceptible to erosion caused by rainfall. And for the purpose of planning that control method, it was judged that a proper way is to assess every plot as the same condition by investigating many experimental results collectively concerning the uniformity of soil condition indispensable for every plot when we conduct and repeat various experiments at this study plot.

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山間開発農地の保全に関する実証的研究
— 試験区の設定と土壌の基礎的諸特性について —

長堀金造，天谷孝夫，マナス・ロシリクル，足立忠司，赤江剛夫[a)]
(農地整備学研究室)

山間の傾斜地における開発畑での土壌侵食防止に関する研究を行うに際し，種々の繰り返し試験を実施するための試験区を設置したが，その場合の最も重要な点は試験区相互間の均一性が確保されるか否かにある．そこで，調査の対象とした国営広島中部台地開拓建設事業地域内において，最も平均的な傾斜面をもつ地区内から試験区を選定した．即ち，同一斜面でかつ同一土質と予想されるので，試験区を更に細分したA，B，C，Dの4試験プロットはすべて同じ条件を具備していると考えられるが，より入念に各プロットの土壌特性から均一性を判定するのが本試験の狙いであった．

供試土壌は，各プロットの上下端及びその中間の3ヵ所から採取し，全てを混合してプロット全体の土壌性質が評価できるような方法をとった．先ず，土壌の物理性を明らかにするために真比重，間隙率，土壌構造，粒径分布，保水性，受食性等について試験し，それらの結果から本試験区土壌の一般的特性を明らかにすると同時に，各試験プロット間の均一性について検討を行った．諸結果を考察すると，以下のようにまとめられる．

1) 本試験区土壌は構造が未発達であり，分散作用に対する抵抗性を示す団粒化度が低く，かつ透水性，保水性を保証する間隙率が小さい．pF 値もそれらの結果を裏付けている．
2) 粒径分布は，礫から粘土までまんべんなく混合されたマサ土特有の性質を示している．
3) 土壌の分散率，侵食率が高く，受食性の土壌であると判定される．従って，本地区での営農に際しては，適切な土壌侵食対策を講じる必要が極めて大きいことを明らかにした．
4) 以上の諸結果から総合的に評価して，各試験プロット間の土壌の諸性質には明かな違いはみられず，今後それぞれ同一条件を有した試験区とみなして実験を行っても差し支えないものと判断された．

a) 滋賀県立短期大学農業部